ANALYSIS OF HUMAN INTUITION TOWARDS ARTIFICIAL INTUITION SYNTHESIS FOR ROBOTICS

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ABSTRACT

Human intuition is an unconscious mental process aimed to solve problems without using a rational decision-making process. Meanwhile, the artificial intuition is a limited representation of human intuition, and it models intuitive ability of solving problems in order to be implemented in machines. In this work, we performed an analysis about analogies between human and artificial intuition using INPUTS, PROCESSING, and OUTPUTS. Mainly, we have focused on synthetize algorithms that improve robot performance in pick and place tasks, simplifying the processing stage (decision-making process), by reducing the complexity the set of instructions needed to solve the task. The experiments show that we reduced the execution time of the task aided by the algorithm and also augmented its accuracy. This new approach of artificial intuition can be exploited to solve current unsolved problems of artificial intelligence.

KEYWORDS

Artificial Intuition, human intuition, algorithms, simplify problem-solving process, Bioinspired mathematical expressions.

1. INTRODUCTION

In the past few decades, scientific community has worked on improving the effectiveness of machines, particularly of robots. When an artificial agent (such as robots) needed to solve problems more efficiently, the artificial intelligence had been the obvious option.[1] In literature, this approach is reported as the generation of *artificial consciousness* in machines and is mainly achieved through Artificial Intelligence paths.[2, 3] Another approach is to provide machines with an *artificial unconsciousness*, e.g. automation,[4] *behavior based robotics* with reactive and deliberative behaviors,[5-8] and recently the *artificial emotions* [9-12]. An underexplored approach for the implementation of artificial unconsciousness is the use of intuition. When an artificial agent manifests human intuition properties, then we can say that there is Artificial Intuition. Up to this moment, Artificial Intuition has been studied only from the computational point of view [13-15], nevertheless, Artificial Intuition still needs to be defined and to be modeled in order to apply it to artificial agents such as robots.

We propose that human intuition is embodied in three stages: Inputs, Processing, and Outputs, which can be compared to the same stages in machines. These stages are the most accepted architecture in machines and, here, we correlated each stage to its equivalent in artificial intuition. Then, we analyzed human intuition stages properties to extrapolate them to machine stages towards artificial intuition in robotics.

Additionally, we developed an experimental strategy to study abilities of human being where the intuition may appear. In this regard, we examine the data from the experiment samples to obtain a mathematical model of those intuitive abilities and to synthetize artificial intuition algorithms, which are intended to be programmed in intelligent machines.

In this work, we firstly set a background from the literature, secondly, we studied human intuition and its properties, thirdly we propose a definition of Artificial Intuition, and finally we used an experimental strategy to prove that human intuition stages can be applied in a robotic system.

2. BACKGROUND

2.1HUMAN MIND

Human mind is responsible for understanding, thinking, creativity, learning, emotion, memory, imagination, will, and intuition, among others cognitive functions that recollect and process information in order to regulate the interactions with the surroundings. [16, 17] Mainly there are two recognized sides of mind: the conscious mind and the unconscious mind.

From a cognitive perspective, the conscious mind is explicit, discursive, sequential, rational, and requires effort, larger amount of time to perform, while the unconscious mind is hidden, implicit, associative, faster, and requires less effort to perform.[18, 19] Also, conscious mind is analytic and convergent, operates with rules and is accurate, but can be overflowed when facing with complex problems, in contradistinction to unconscious mind that barely deteriorates with complex situations, even problems with multiple variables.[20]

Intuition is one mechanism from the unconscious mind strengthen by experience, which helps the human to accomplish large number of tasks and we going to explore its advantages and to apply them to artificial agents.

2.2HUMAN INTUITION AND ITS PROPERTIES

Along with the definition, here are written some properties found in the literature that will be the material of the main analysis written for this work. The word intuition comes from Latin, *intueri*, that means “to consider” or “to look upon”, which can be also understood as a *perception*, but also as an implicit knowledge found in the unconscious mind of human beings. Intuition is accomplished through *recognition* of significant information and it synthetizes immediate *decisions* or *actions* without the need of a rational process neither consciousness. Such actions had been described as automatic, rapid and mostly accurate, [19, 21-32] see Fig 1.

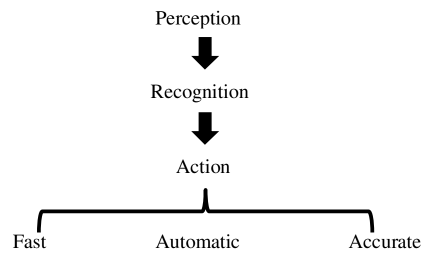

Fig 1. Diagram of Intuition

Human intuition has been defined as capability to act or decide appropriately without deliberately and consciously balancing alternatives, without following a certain rules or routines, and without awareness. This property allows quick actions (e.g. reaction to a challenging situation), which are surprising, in the sense that they are extraordinary in performance level or shape.[28] Intuitive decisions emerge from subconscious without exhaustive deliberation i.e. intuition does not reason nor evaluate all alternatives of solution for a given problem,[19] nevertheless intuition's assertiveness depends on the use of previous experiences and the context of the problem.

Psycho-cognitive research describes intuition as an unconscious mechanism in the human mind specialized in fast and accurate pattern recognition that proceeds from *practice and experience.*[29, 31, 33-36] Also intuition has been described as an implicit or tacit information processing distinguished by been automatic.[27] Intuition is executed with help of a *rational database* of knowledge previously acquired but hidden from conscious mind which the human use for recognize and act rapidly.[37] In intuition, the recognition is based on *mechanisms* that recognize *simple patterns* enabling humans to synthetize decisions.[12, 36, 38] Those patterns are relevant information pieces that help to create the intuitive decision,[26] which means that a single or isolated data is enough for human intuition to get an accurate answer.[34] Human Intuition is regulated by associative, unconscious, suboptimal, effortless, and heuristic rules or syllogisms.[39]

Yet another property for human intuition is multidimensionality, [40-42] which means that intuition is capable to integrate multiple threads of information simultaneously without diminish the quality or accuracy of the response. Human intuition is particularly activated with time pressure to formulate decisions (e.g. a medical diagnosis in the emergency room) [43].

2.3RELATED WORK ABOUT ARTIFICIAL INTUITION

Monica Anderson has been working on alternatives to Artificial Intelligence problems by describing subsymbolic mechanisms programed as algorithms of low computational cost, which are able to solve elemental problems in a bizarre world that she has denominated as a kind of Artificial Intuition [13]. On the other hand, Tao Weidong *et al*[15] suggested a learning system based on intuition through Artificial Intuition Networks as a mechanism of cooperative learning which will provide to the user a game-like experience, making situations more obvious and easier to learn. Finally, Jitesh Dundas *et al*[14] proposed an algorithm of artificial intelligence based on intuition-like mechanism which includes grossly the following stages: 1) obtaining initial conditions, 2) obtaining an equation from recollected pieces of human experiences, 3) obtaining of weight values of importance, 4) recognition of waste information, 5) application of adjustment factors to calculate the final answer, and 6) displaying the answer to the user.

In summary, so far it had been stated that: Artificial Intuition is based on *micro-intuitions*, so named because they are programmed as low cost computational algorithms,[13] Artificial Intuition can be a collaborative software design between programmers and users,[15] and Artificial Intuition can be programed as a pattern recognition using artificial intelligence tools.[14]

It is important to mention that none of the previous authors have clearly defined Artificial Intuition, besides its particular properties have not been proposed. Additionally, a strategy to synthetize Artificial Intuition is still required.

Artificial Intuition is potentially applicable to any artificial system, but in this work, the authors will focus the Artificial Intuition to robots.

3. ARTIFICIAL INTUITION

3.1ANALYSIS OF HUMAN INTUITION

We have enumerated some sentences about *Human Intuition* from the properties found in the literature as follows:

A) Intuition is a kind of *unconscious information processing* within the human mind.

B) Intuition does not follow a rational path to solve problems. See Fig 2.

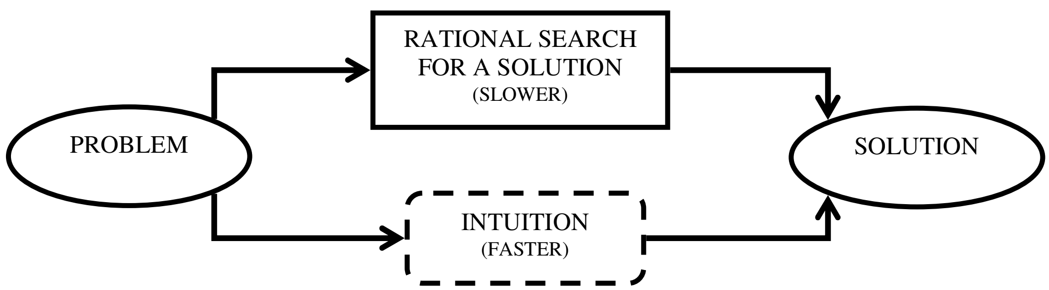

Fig 2. Intuition is a shortcut that avoids the rational search for a solution and generates a solution to a given problem.

C) The intuitive *process* is automatic, associative, mostly uses heuristic rules that does not require mental effort (low cost).

C.1) The process is executed as soon as the information is received.
C.2) The process uses a previously defined relation between particular inputs with particular outputs.
C.3) The process is constituted by a set of modules generated by previous experience or practice. The modules are stored in the unconscious mind and they can be accessed when is necessary.

D) Intuitions are activated *when* inputs (stimuli) are presented to the individual.

D.1) The inputs are basic or incomplete pieces of information; they are simple components of the problem.
D.2) The inputs are related to the task and the context changes radically their influence on the intuition.
D.3) In many problems solved by intuition, the inputs are in multiple channels or different types of information.

E) Intuition generates a unique *output* (solution), which is fast, unambiguous, and satisfactory.

E.1) The outputs accuracy depends directly on experience, context and practice.
E.2) Intuitions shows up when new circumstances have to be solved in a short period of time.
E.3) Many problems need to be solved before they occur, so the intuitions also are able to do *predictions*. Intuition finds out the most probable possibility.

In summary, the intuition can be organized as shown in Fig 3, in order to establish the analogy with the common architecture of artificial agents, including robots, that is Inputs (e.g. sensors), Processing (e.g. microcontrollers and programs), and Outputs (e.g. mechanics and actuators).

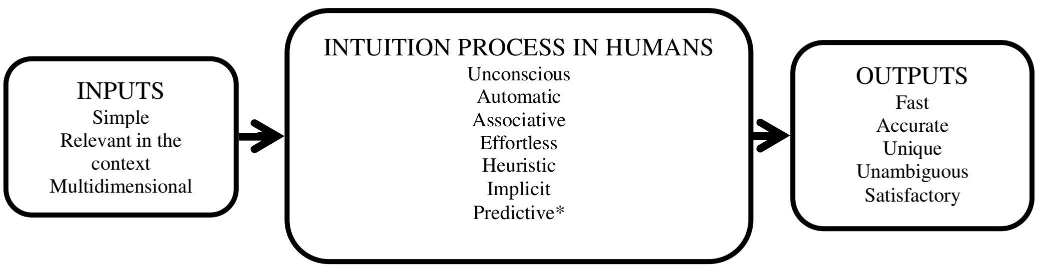

Fig 3. In the human Intuition, we have ordered the process in three stages, as in machines INPUTS, PROCESS, and OUTPUTS.

3.2A SYNTHESIS OF ARTIFICIAL INTUITION

In this work, the authors take some properties from the human intuition in order to describe what Artificial Intuition can be, and how can be used in machines, especially in robots. We have to focus on the best responses produced by intuition, in order to augment accuracy in robots.

Artificial Intuition is an automatic process, which does not search rational alternatives, jumping to useful responses in a short period of time, and is mainly focus in to provide responses without iterative search of solutions for a given problem. Normally, the process that controls a machine needs feedback to know if the action control was right, but with the artificial Intuition, the answer is assumed to be correct, and no further feedback is implemented, in the sense that there is no self-evaluation.

Essentially, Artificial Intuition processing is based on simple algorithms created to solve common problems without complex solving problem mechanisms. Those algorithms use data related to the task as inputs, and the stimuli can be different in nature from the task, for example, a noise can detonate a mechanical response.

We propose that the Artificial Intuition algorithms can be embodied as mathematical expressions that directly model a previously studied phenomenon, such as obstacle avoidance in robots. Yet another characteristic is that Artificial Intuition generates a unique answer to a problem as fast as the inputs are received, discriminating other possible solutions, hence the answer is unambiguous. Finally, Artificial Intuition can use the *most probable answer*, by defining *predictive functions* in the algorithms.

In order to implement Artificial Intuition algorithms, a new conditional construct in programing is proposed, that is *when*. In this new decision structure, it is determined if the conditions are present and then is calculated a single answer and obviating other possibilities. In other words, we propose to eliminate the *else* of the *if* structure and name it as *WHEN*.

Concordantly to human intuition, we establish the next organization for Artificial Intuition, in Fig4.

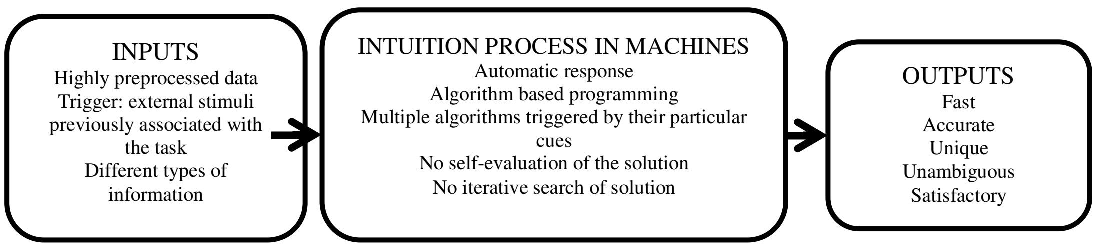

Fig 4. In the Artificial Intuition, there are three parts to consider as in any machine: INPUTS, PROCESS, and OUTPUTS.

In the following section we propose a strategy to embody the previous concepts into mechanism that can be used in machines.

4. ARTIFICIAL INTUITION ALGORITHMS

The strategy that we propose to synthetize Artificial Intuition is by analyzing human intuition during the performance of a task and it is as follows: A) Collect data from human abilities achieved by intuition, B) Analyze implicit characteristics of the intuitive performance (such as patterns, templates, among others), and C) Synthetize the algorithm that emulates the intuitive action/reaction, see Fig 5.

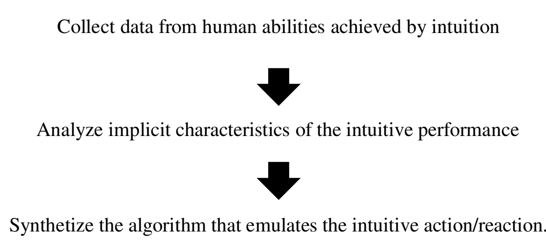

Fig 5. The strategy to synthetize Artificial Intuition Algorithms

4.1 COLLECT INFORMATION FROM HUMAN INTUITIVE ABILITIES.

In order to acquire data from a task executed by a human, an experimental procedure is required; also a *testbed* has to be designed accordingly to the task we want to study in order to collect the correct data, for example, use the adequate sensors to collect trajectories should measure position, speed, and acceleration. The two main conditions for the experiment are that: 1) The task presented to the participant has to be evident enough to be solved, (NOTE: the task complexity depends on the background of the ability that is going to be studied), and 2) The participant is urged to solve the task as fast as possible and with the first solution that comes to his (her) mind ("*not thinking hard*"). Some recommended complementary actions are to record sessions of interviews on video along with the data, and a short questionnaire about the background (e.g. studies, particular abilities) and personal data (e.g. age, gender) of the participant. Also the adequate quantity of data from an adequate population sample has to be defined.

4.2 ANALYZE THE INFORMATION CONTAINED IN THE DATA

After the data capturing, it is mandatory to organize the database for the purpose to identify, classify and associate the types or types of information, and display them in diagrams, charts, tables, or else, as needed to properly represent and appreciate relations, patterns, or some archetypes. The following step is to verify that the findings are not fortuitous happenings, accidents, errors from the acquisition system, or other disturbances. The mathematical model can be selected by the researcher freely.

4.3 SYNTHETIZE THE ALGORITHM THAT EMULATES THE INTUITIVE RESPONSE

From the findings in the previous step, we propose to model the intuitive action through mathematical expressions. The expected outcome is to make a close imitation of the captured intuitive action, which is associated directly with the task. One way to accomplish that is to formulate an *algorithm* based on the mathematical model. The inputs of the mathematical expression have to be acquired from the surroundings, from the objects *per se* or from a previously acquire database, and always are related to the task. The presence of the inputs is the responsible for triggering the algorithm to avoid its execution all the time, which leads to spend machine processing needlessly. As we can see, the synthesis of an algorithm in this manner we accomplish to emulate the human intuition particularly in the task we analyze; also we fulfill the properties of the intuitive outputs which are to quickly obtain the answer that has to be automatic, and provides a satisfactory solution. The algorithms are the *templates* of the task that has been made by intuition.

5. THE STRATEGY INTO THE ROBOTICS FIELD

5.1THE SETUP

The strategy we propose to synthetize algorithms of Artificial Intuition for robots include to design a particular testbed directly associated with the task we want to measure when is done by a human. In robotics, this step implies that we have to develop a robot-like instrument that measures those variables required to measure the task.

Let's take a *case study* in order to illustrate the strategy, we choose a task of pick and place an object, particularly the movement of the end effector from an initial point to a final point, which we call *relocation movement*, and we going to measure it as series of points in the Cartesian space (x,y, and z), and with such information, we can define a *locus*, and a series of locus define workspaces. If we add other kinematic component to a locus, such as the speed, we define trajectories. The general case is drawn in Fig 6, where the outer shape represents all the positions that a robot can reach with its articulations (entire workspace). The middle shape represents all the different robot's positions that can solve the task (a workspace defined by the task). Finally, the inner shape involves a human being, who decides the positions, and speeds accordingly to its intuition to solve the task. And that is what we going to measure.

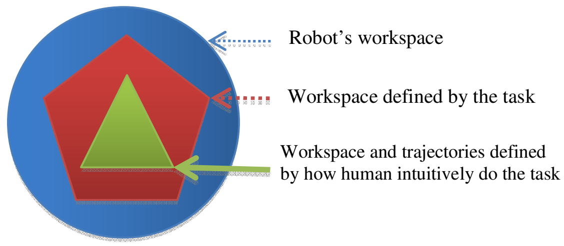

Fig 6. The spaces where the robots exist and operate

The subsequent step is to manufacture a testbed. We have made a five degrees of freedom robot-like device able to capture angular information and to transform the end-effector's position into Cartesian coordinates (x,y,z). In the publication refereed in [44] there is more engineering details. In the Fig 7 is shown the mechanical device.

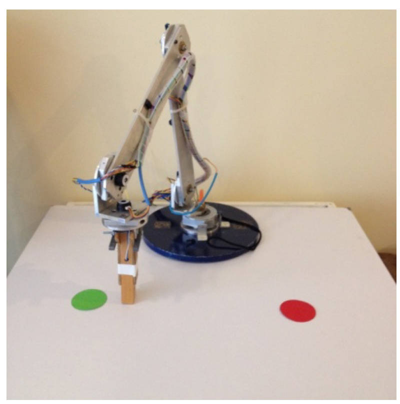

Fig 7. The mechanical testbed

Next, a group of twenty persons were tested to relocate the end-effector from a point to another. In the Fig 8 we see a group of photos where an example with a person moving the end-effector from an initial position to a final position.

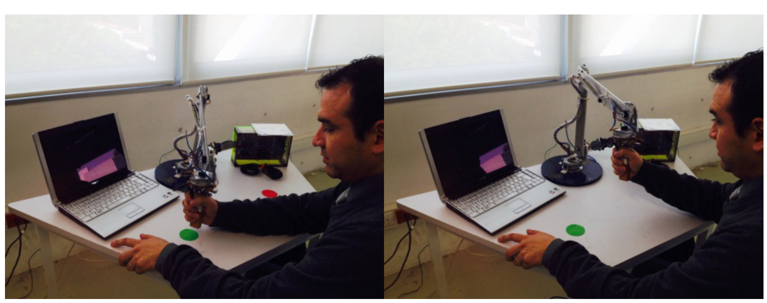

Fig 8. Sample of a person doing the task.

In the next figure we add the results from the measurement system showing the data of the participants in only one graphic, see Fig 9.

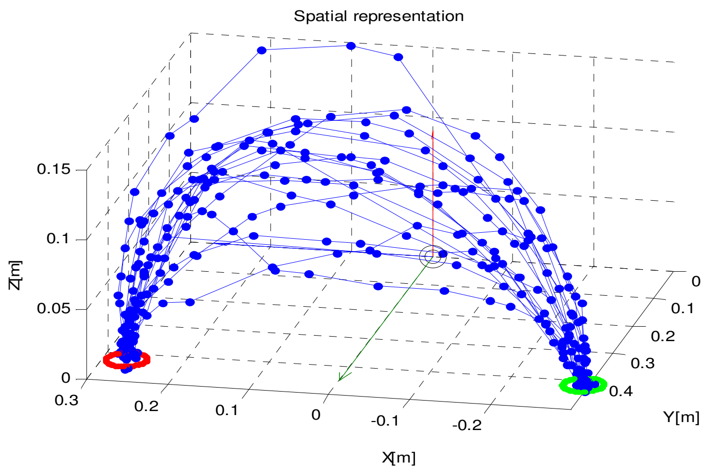

Fig 9. Samples from the participants

We simplified the results as a single locus, in order to formulate a mathematical model. The locus is built through a method of "centroids", which consists on divide the space in constant slides of data and obtaining their average for every slide. The result is shown in Table 1 and in Fig10.

Table 1. Data from the Results Measurement System

Time	**x [m]**	**y [m]**	**z [m]**
0	-0.27400398	0.40327761	-0.00994005
0.12845833	-0.20869161	0.40046594	0.05971191
0.2545636	-0.15183845	0.39591235	0.08613222
0.3722511	-0.0946539	0.39798651	0.10616616
0.49220348	-0.02836206	0.40473695	0.12310821
0.60200348	0.02764612	0.40234302	0.1288216
0.71879295	0.0889579	0.41084102	0.12656323
0.83312628	0.15555609	0.40430164	0.12221002
0.95370693	0.21349928	0.40643035	0.08948734
1.07841485	0.2686226	0.42478177	-0.00678217

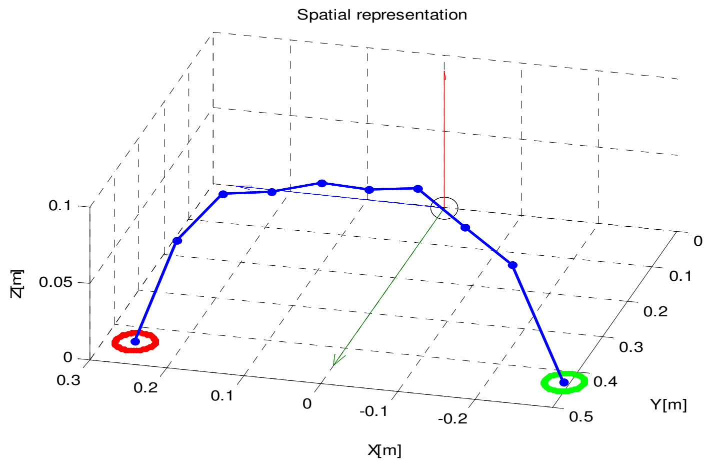

Fig 10. “Centroids” from the results.

And with the objective to find models, we decompose the locus in three components: x (Fig11), y (Fig12), and z (Fig13).

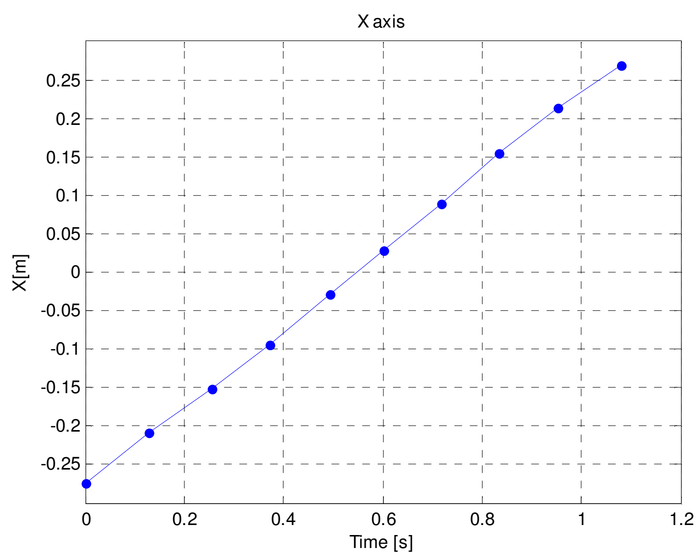

Fig 11. X axis behavior, which is adjusted to a *line*

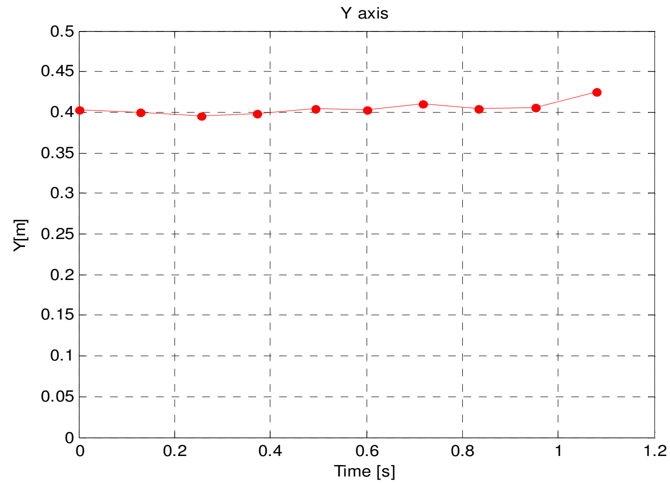

Fig 12. Y axis behavior, which is adjusted to a *line*

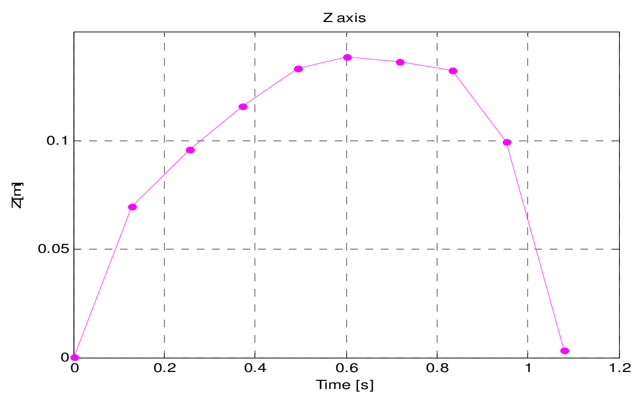

Fig 13. Z axis behavior, which is adjusted to a *line* and to an *arc* function

From the morphological characteristics seen on each axis (x, y and z), we have adjusted their behaviors into the following curves:

$$x_{at} \quad f_x(parameter) \quad Line_x(parameter) \qquad (1)$$
$$y_{at} \quad f_y(parameter) \quad Line_y(parameter) \qquad (2)$$
$$z_{at} \quad f_z(parameter) \quad Line_x(parameter) \mid Arc_z(parameter) \qquad (3)$$

Note that axis x and y are lines, in contrast with z which is a line plus an *arc*. In the first two cases, the lines are evident to perceive in the charts, but the third case, the adjustment of axis z to an arc, maybe evident but we added a line to attend to any case in the three dimensional space.

Each function (*f*) of the equations shows the dependence of a parameter, which is needed to move in time from de beginning (0%) to the end (100%). This parameter can be associated with other time function, as seen in velocity profiles which resembles trajectories. In the other hand, the parameter can be provided by a person as seen in teleoperated systems.

Model Equations and algorithm. The inputs are three points, the initial point I (x_i, y_i, z_i), the final point $F\ (xf, yf, zf)$, and the point given by the human operator $M\ (xm, ym, zm)$. The parametric equations are driven by a PACER (ϑ), valid within the rank of [0,1], if it is less than 0, $\vartheta = 0$ and if it is greater than 1, $\vartheta = 1$.

$$x_{ia} = \vartheta * (x_f - x_i) + x_i \quad (4)$$
$$y_{ia} = \vartheta \times (y_f - y_i) + y_i \quad (5)$$
$$z_{ia} = \vartheta * (z_f - z_i) + z_i - A * \sin(\vartheta * \pi) \quad (6)$$

Where:

$$A = \frac{1}{4}\sqrt{(x_f - x_i)^2 + (y_f - y_i)^2 + (z_f - z_i)^2} \quad (7)$$

Note that A is the amplitude of the trigonometric *sin* function. A was a *finding* from the experimentation, which result to be a *quarter of the distance* between the initial and final points.

These three equations were transformed into a subroutine programed in a computer to assist a robot during a task.

5.2 EXPERIMENT WITH THE ALGORITHMS PROGRAMED IN A ROBOT

We use a simulation programed in a virtual human-machine interface and a person operated the robot in the screen of a computer. The person moved a robot-like master device which references was transferred to the PACER and the equations were solved for every value of this parameter.

In the conducted experiments, a person interacted with a master device and with a virtual interface (see Fig 14). Before initialize the experiments, the researcher's instruction to the person was to move the robot's end effector from the initial point to the final point and go back. The only feedback to the operator was a 2D screen (see Fig 14). The person had no control over the camera´s perspective of the image of the robot in the screen.

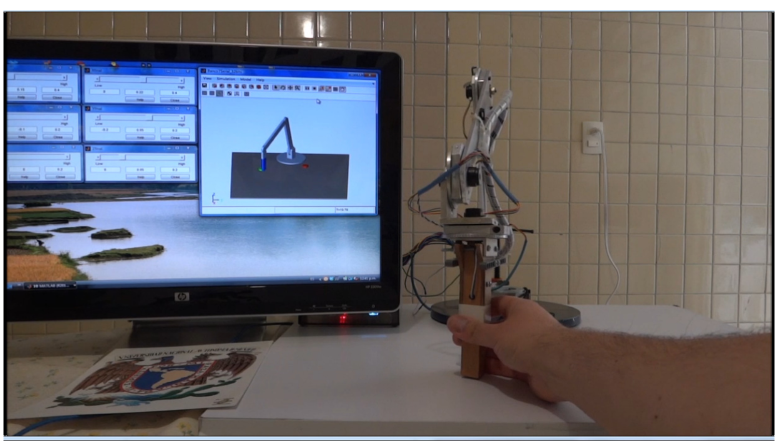

Fig 14. Experiment's location view.

The data of interest that were measured was:

1. The time elapsed from the initial point to the final point and go back. The time is measured in seconds.
2. The positions of the end effector and the master device in the marks of interest (initial and final positions of the transfer). The positions are measured in meters.

There were two types of experiment, one with the algorithm assistance and the other was without the assistance of the algorithm.

5.3 RESULTS

Below are the results of the time needed to complete the relocation task *with and without* the artificial intuition algorithm, see Table 2.

Table 2. Time of the tests with and without artificial intuition

Experiment number (different sets of initial and final points)	Without artificial intuition (s)	With artificial intuition (s)
1	4.9652	1.0366
2	12.3759	0.3223
3	7.9116	3.4473
4	12.3759	3.0902
5	8.0884	3.0009
6	5.2330	1.2152
Average:	**8.4916**	**2.0188**

We calculated the error on the initial and final positions by comparing them with the original coordinates of reference. The references of the initial and the final points in Cartesian coordinates (x,y,z) were different in each set of experiments. In the following figures we show the errors. In Fig 15 are the errors of initial point and in Fig 16 are shown the errors of the final point.

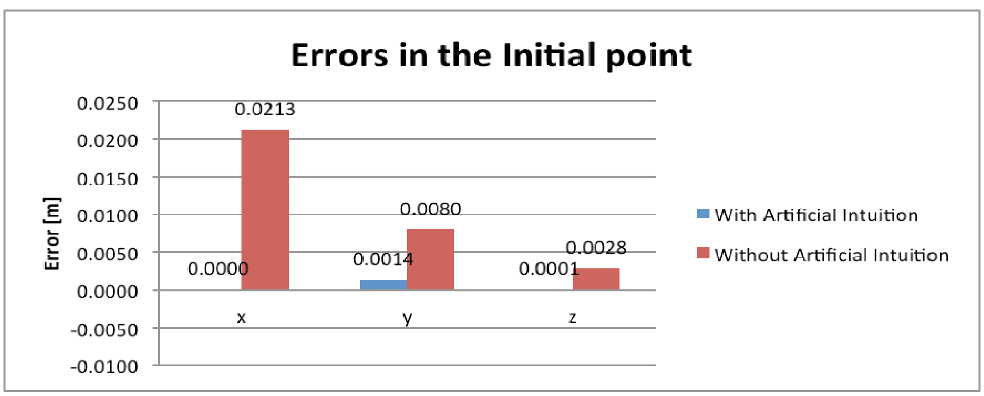

Fig 15. Errors of the initial point with and without Artificial Intuition

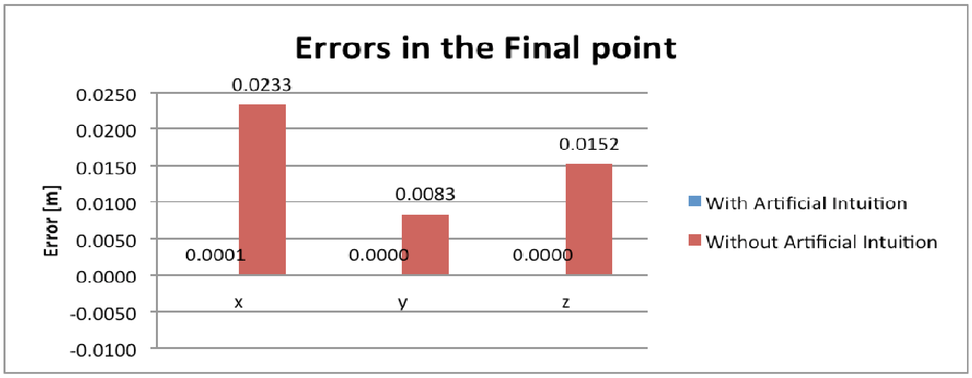

Fig 16. Errors of the final point with and without Artificial Intuition

6. DISCUSSION

The human intuition is merged in how a person carries out a task. Intuitively, the human defines an intangible workspace for a particular task and execute it. We have obtained samples of that workspace as a set of loci, in Cartesian coordinates. We noticed that there is more than one way to represent the workspace as mathematical expressions, but in order to present a model for it and to program the artificial intuition algorithm we choose geometric and trigonometric elements. Specifically we use basic elements of the line equation and a sinusoidal wave to construct the model. These elements provide some properties, which are: a) for every set of inputs exists only one solution, b) the equations are derivable, c) the expressions are autonomous of the time, and d) the synergy of the equations is particular for the task but can *interact* with other equations generated from other tasks, (e.g. orientation, assemble, among others in robotics). The algorithm programed from the equations can solve the task for any pair of points (initial and final points), also the algorithm contains very simple statements such as arithmetical operators. As consequence the result obtained from the algorithm is fast, automatic, unique and mostly accurate.

7. CONCLUSIONS

Artificial Intuition is a limited representation of intuitive abilities of human beings. The artificial intuition deals with fast, automatic and accurate solution generation during machine´s performance. We had made analogies between human and artificial intuition using their properties organized in the three stages of machine's architecture: INPUTS which elements to provide information from the surrounding; PROCESSING, which is the programing stage and we focused to diminish complexity; and OUTPUTS, which need to be intuition-like i.e. automatic, fast and augment accuracy. Additionally, we have found that the processing stage can be shortened, abbreviated, or simplified (make concise) which is the way of intuition to perform faster that the conscious mechanism such as the artificial intelligence methods. Also we proposed a strategy to synthetize artificial intuition algorithms from the actions made by a group of people and give an example about solving a task of pick and place with the conditions given in the strategy.

From the results with the virtual robot system programed with the artificial intuition algorithms, we observed the following:

In the direct operation (not assisted by artificial intuition), the time that the operator requires to complete the relocation task is at least thrice the time required in the assisted operation. Regarding the accuracy for the task we found an error within the range between ~0.0001 or less and 0.0014 meters when the artificial intuition was present during the task execution in comparison with an error within the range between ~0.0028 and 0.0233 meters when the task was non-assisted by the artificial intuition.

After we have been experimenting with this kind of algorithms, we have found that a new control structure in programing is necessary. For instance, we have used to program with *if* sentences but for Artificial Intuition, the algorithm only is executed *when* the adequate stimuli triggers the response.

The artificial intuition algorithms are meant to enhance machine performance, for example, in the robots, we diminish execution time of the task and procure accurate solutions.

In the future we have foreseen the existence of autonomous systems that exploit the model provided here. We currently are studying kinematical properties such as velocity and acceleration during the intuitive realization of tasks from humans in order to generate algorithms to provide intuitive autonomy to robots.

Moreover, the strategy proposed here to capture Artificial Intuition can be used for capture not only complete movements of body segments but complex and multivariable problems where intuitive decisions can appear, such as driving cars or sport playing.

Artificial Intuition is a multidisciplinary area that integrates sciences such as informatics, and psychology, to study, create, and design agents capable of emulate some properties of human intuition. Also it is a branch of Artificial Intelligence dedicated to generate fast, accurate or trustworthy, and automatic responses using low or poor quantity of information.

Finally, Artificial Intuition described in this paper implies reorganization in artificial intelligence. On one side are those who emulate human consciousness, such as rational agents, neural networks, expert systems, among others, and then there are systems dedicated to emulate human mental unconscious functions such as emotions, behavior and now the Artificial Intuition as one of its main representatives. So the two branches of artificial intelligence (artificial conscious and artificial unconscious) may achieve a holistic artificial mind for autonomous and semiautonomous robots.

8. ACKNOWLEDGMENTS

The authors would like to acknowledge the support given by the DGAPA of UNAM, through the project PAPIIT IN117614, titled: "ROBÓTICA INTUITIVA, ADAPTABLE, REACTIVA, HÍBRIDA Y MÓVIL APLICADA AL SERVICIO, EL RESCATE Y LA MEDICINA” during the realization of this project.

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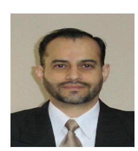

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